MOUNTAINTOP REMOVAL MINING/VALLEY FILL ENVIRONMENTAL IMPACT STATEMENT TECHNICAL STUDY

PROJECT REPORT FOR TERRESTRIAL STUDIES

October 2002

Terrestrial Plant (spring herbs, woody plants) Populations of Forested and Reclaimed Sites

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EXECUTIVE SUMMARY

The data presented in this report were collected in the spring and summer of 2000. They examine the pattern of revegetation of mountaintop removal and valley fill mining sites in southern West Virginia. The forests that are being removed by mountaintop removal and surface mining activities are located in the Mixed Mesophytic Forest Region. This region has very high biodiversity at the community level, and is among the most biologically rich temperate regions of the world (Figure 1. Hinkle et al. 1993). These forested mountaintops are predominantly being replaced by grasslands, although grasslands are not a naturally occurring habitat in this region (Figure 2. Hinkle et al. 1993). Blocks of young trees, some exotic, are often added to the final revegetation mix after grass establishment is successful. There is now great interest in developing and implementing mining practices that will have the least impact on future economic and ecosystem health.

Fifty-five transects on sites ranging in age from eight to twenty-six years since revegetation were visited in southern West Virginia by this investigation team. Plant species, sizes, and distribution were recorded across these sites for all woody species. Data from adjacent, unmined mature forests were also recorded. Invasion of native species onto reclaimed mined sites and valley fills was very low and restricted to the first several meters from the adjacent forest edge. Most of the plants found on mined sites were in the smallest (<1" diameter) size class, suggesting that the sites are stressful to plant growth and survival. Many of the species found in adjacent unmined forests are not present on the mined sites. Poor vegetation development with time was typical of the sites reclaimed after the 1977 SMCRA law. Diversity was significantly lower on the mined sites than in adjacent forests.

These data and other published studies support the conclusion that mining reclamation procedures limit the overall ecological health and plant invasion of the site. Plant invasion and success are dependent upon reclamation practices. Less soil compaction, smaller mining areas, healthy soil profiles, and native plant material all would support a healthier ecosystem return, although full premining biodiversity may be difficult to achieve. Sites that were reclaimed with pre-law protocols supported a richer flora than post-law sites, but this may be attributed to small scale, less compacted mining procedures. They also contained more native plants and represented all age classes unlike the post-law sites.

Herbaceous species were also studied on nineteen transects, in mature forests and on transects adjacent to mined sites. The loss of spring herbs on engineered sites was highly significant compared to forests away from mining activity. Information gathered from this aspect of the study shows that monitoring the forest herbs adjacent to mining activity is an additional useful indicator of environmental impact. The heavy compaction of the artificial slopes created during valley filling also contributes to these slow invasion rates. Additionally, the grassy vegetation mixes usually installed during revegetation are known to hinder the ability of the native plant species to establish. The poor invasion and growth of native vegetation across these study sites support the conclusion that these lands will take much longer than the natural time scale observed in old field succession to return to the pre-mining forest vegetation.

Objectives:

The objective of this study was to determine the patterns of terrestrial vegetation on areas affected by mountaintop removal mining and valley fills in the southern Appalachian region, and on adjacent, non-mined areas. Specific goals were to identify plant species present, determine the relative numbers of species present, record the size class distribution based on diameter at base or diameter at breast height of each species, and to document the pattern of vegetation from toe of slope to top of slope and from forested areas to mined areas. These data will enable investigators to understand the potential for re-establishment of native vegetation and document the actual change in vegetation since revegetation of the mined sites.

Importance of the objectives:

It is important to know the fate of the mined lands after reclamation, to determine the potential for re-establishment of surrounding native vegetation, and to see if a flora different from the vegetative mix installed upon reclamation can establish. The soils, seed pool, and local conditions on mined sites are quite different from the original conditions. It must be understood if mined areas will develop differently from the forested terrestrial communities surrounding the mined sites. These data are also needed to assess the quality of the habitat for animals of the region. If current reclamation methods are creating different habitat types, this must be known precisely, so that regulatory actions can be created to account for such changes.

METHODS:

Tree and shrub studies - site selection:

In order to assess the progress of invasion of woody species onto reclaimed mine lands, sites were selected that had a remnant forest adjacent to the mined area. A remnant forest is a forest that is directly bordering an active mining site or in this case, reclaimed sites. They are passively disturbed by mining activity through many ways including pollution, ground disturbance from blasting, hydrology changes and siltation, and increased edge area. These reclaimed areas were considered most relevant for this study because they included a seed source for the mined area, therefore offering an opportunity for woody species to invade the open, disturbed land. Study of mined lands adjacent to mature forests, of course, maximizes the potential for invasion of species, and potentially weighs the data sets towards higher invasion rates. However, it is necessary to see invasion, and the intensive sampling of edge areas gives the investigator a higher potential for determining invasion rates.

Sites across the mining region of southern West Virginia were selected to represent a wide variety of ages, conditions, and treatments. The sites in this study were recommended by EPA, WVDEP, FWS, and mining officials and engineers who worked for the mining companies that participated in the study. Knowing that the goal of this study was to record re-establishment of woody vegetation on mined lands, mining officials (list of personnel can be provided by investigators) directed our team towards the richest sites available. All of the recommended sites were studied and included in this report, in standing with the policy to visit every site recommended. At each specific locale, transects were positioned in a standardized location and vegetative cover and density were similar. The total number of forest transects surveyed and reported is 25 and the total number of mined land transects is 30. Ten different mine properties were surveyed, with ages ranging from eight to twenty-six years since revegetation. Emphasis was on surveys of sites that were older, but reclaimed after the 1977 surface mining law (SMCRA) was put into effect. Changes in reclamation protocols necessitated by that law caused important differences in reclamation practice (Vories and Throgmorton, 1999). A complete list of study sites is in the Appendix (Table 1).

Tree and shrub studies – data collection:

The first aspect of this study involves twelve transects that were run vertically down slope from a mined land (i.e. valley fill, mountain-top removal area, backfill, or contour mine) into an adjacent, mature, remnant forest apparently unaffected by mining activity (Figure 3a). (Many of these forested sites were once logged and showed vestiges of former rough logging roads. Consequently, these forests have been modified by human activity and are not considered intact or pristine forests. However, all forested areas contained large, diverse canopy trees with well-developed stands and unexcavated soil.) The transect line was continuous from mined area to the adjacent remnant forest, or in some instances started in the remnant forest above the reclaimed site and ran down into the mined land.

It is important to note the structure and nature of the *valley fills*. Transects were arrayed from top of slope to toe of slope (toe of slope in this study was defined as the bottom of the hill/fill where the ground leveled off, and/or the stream bank was reached), and ran the entire length of the fill. Because of the triangular geometry of valley fills (Figures 3a and 3b), areas at the toe (base) of the slope were surrounded on two sides by remnant forests. They were much moister areas than the top of the fill, due to storm water run-off and ground water. Because the toe of slope is wetter, much narrower, and much closer to remnant forests (on both sides), we see an increase in stem density that is indicative of an "edge effect." Some of the valley fills had forest remnants at the top of the slope as well as at the bottom, therefore creating two zones of forest edges. Where this was the case, the top forest remnant was sampled and the bottom one was not.

There were an additional 43 transects studied where it was not possible to run continuous transects, as above. In these cases, the forest remnant transect was run perpendicular or adjacent to the mined area transect, as shown in Figure 3b.

Data were collected during the year 2000 growing season only. The presence of woody plants on these sites represents the reproductive performance of many years. The boundary, or edge, between forests and reclaimed mine land was recorded for each transect and is the "0" point on all data sets and graphs. The point-quarter sampling method was used to survey the woody plant community (Barbour, Burk, et al. 1999). This technique was used as it allowed the investigating team to cover the most ground, the most sites, and collect the most data points in the time frame given. There is a potential to underestimate rare species with this technique, as a census of all plants in an area is not done. However, a species effort curve performed on the data indicates that few, if any, rare species were missed given the large data set that covers thousands of individual plant records. Consequently, the field sampling technique is representative of the woody species on site.

At each sampling point, located at 20 meter intervals along the transect line, the area was divided into four quadrats. In each quadrat the distance was measured from the sample point on the transect line to the nearest woody plant and recorded for three different size classes, for a potential of twelve individuals per transect point. The size classes were defined as “small” (0-2.54cm), “medium” (2.54-7.62cm), and “large” (more than 7.62cm) based on diameter at base of stem. For each of these stems, the nearest neighbor’s distance and species identification were recorded, as well as the distance to the nearest conspecific (individual of the same species). Trees that were obvious parts of an implemented planting program (determined by plantation spacing and diameter at breast height) were not included in the counts, as these did not naturally arrive on the sites and are not part of any invasion process. Any offspring produced by planted individuals were included in the data, however. We were not interested in survival of the planted trees, as all planted species we encountered are either forestry created hybrids or non-native and in fact illegal to plant in many states. Data were entered on computer databases for further study. Leaves and stems of questionable plants were collected and keyed out using herbarium specimens. Occasionally, specimens could not be keyed to species because they were barren of flowers or fruits; it was impossible, given the rapid time frame of the study, to return to each site at other seasonal times in the year 2000 to search for reproductive specimens.

Tree and shrub studies –data analysis:

Comparing the mined sites to the adjacent remnant forests is difficult at best. Mines are viewed by some as representatives of “primary successional soil/plant systems.” Comparing them to the “native forest stands [as] largely secondary successional systems” is therefore like comparing apples and oranges. (W. Lee Daniels, personal communication). First, the mined lands are <u>not</u> primary successional landscapes. Primary succession is defined as “The development of an ecosystem in an area that has never had a living community….. Examples of areas in which a community has never lived before would be new lava or a rock from a volcano that makes a new island or a new landscape, or a sand bar that arises from shifting sands in the ocean” (University of North Carolina Wilmington). The question is not how the data were compared, but the task set before us was to document the invasion process from forest remnants to reclaimed land, to describe the vegetation and note patterns based on our knowledge and experience as restoration ecologists. We documented the successes and failures of natural recruitment onto these early successional landscapes, and analyzed our findings with statistics that allowed for such comparisons, which follow.

As previously mentioned, the objective of this terrestrial study was to determine the success of woody plant invasion onto the disturbed mining areas. The data were examined in several ways. Transects were categorized as one of six types: continuous forest (CF); remnant forest (RF); valley fill (VF); mountaintop removal area (MTR); backfill (BF); or contour mine (CM). Continuous forests are forests located away from mining activity and therefore not significantly impacted by mining activity, whereas remnant forests, as previously defined, are forests directly adjacent to and affected by mining activity. Remnant forests are typically smaller parcels than the continuous forests, but this is not a defining characteristic. Data were displayed within each of the six categories by the three size groupings of plants: small; medium; and large. The density of woody plants by size class was also determined. These densities were compared in order to evaluate the progress of the woody invasion. Species lists of forests and mined areas were developed and comparisons between native forests and mined lands were performed. Plant diversity was estimated using the Shannon-Weiner statistic, which includes measures of number of species and their relative abundances. For example, if you had two stands with the same number of plants and the same number of species, they can be distinguished from one another if one stand has these species in more or less equal proportions; a more diverse stand would have these species in more equal numbers.

Herb studies – site selection:

Nineteen forested sites, considered to be either "intact" forest (11) or "engineered" forest (8), were chosen to evaluate the herb community, adjacent to the EPA aquatic biology team's locations. The terms "intact" and "engineered" forests comply with EPA terminology and are equated to "continuous" and "remnant", respectively, as described in the paragraph previously. Sections of watersheds that had been mined (the engineered forest) and areas that were distant from mining activity (the intact forest) were selected. Sites are listed in the Appendix (Table 2). This protocol allows comparison and correlation of herb data with the aquatic study, for a more complete understanding of these sites.

Herb studies – data collection:

The study team visited all sites during April and May 2000, to sample the spring herbaceous vegetation. Early season sampling of the herb flora was necessary, as many spring herbs often complete their life history before the summer months, then persist underground until the following year (Schemske, et al., 1978; Bierzychudek, 1982). Transects were sampled every 10 meters, starting at the base of the slope, up hill for an additional 50 meters. It was determined by the investigating team that the herb cover significantly diminished around 40 or 50 meters from base of slope, and data from a broader geographical range could be collected if this was a decided end point. At each sample location, a 5x1m plot across the face of the slope was censused for all herbs. Species identity and stem count for each species were recorded for each 5x1m plot. Samples of species were collected for herbarium records and identification verification.

Herb studies – data analysis:

Data were summarized to determine relative distribution and number of species on undisturbed forest slopes compared to forest slopes adjacent to disturbed areas (i.e. mines and wide road cuts). These data were entered in a database for statistical analyses to determine vegetation distribution patterns. Shannon-Weiner Index of Diversity was performed to determine diversity values for both forest types using mean number of stems counted and mean number of species present in both forest types.

RESULTS:

TREE AND SHRUB STUDIES:

Presence of trees and shrubs on the study sites:

The 99 species listed in Table 3 were found collectively on the 25 forest transects and 30 mined transects. Table 4 shows the differences in species composition across these two types, ranked from most to least commonly present. The species did not have to be abundant at a particular site to be included, merely present on the site (i.e. whether the species has one or one thousand individuals, it is recorded as "present"). These numbers do not include data that were collected from contour mine sites or their associated remnant forests, which have been treated and reported separately, so the sample size here is 23 forest transects and 25 mined transects. Most of the species found in the majority of forest transects were found on only a few mine transects, with the exception of *Acer rubrum*, *Liriodendron tulipifera*, and *Rubus* sp., which are regularly found as small plants in disturbed areas. There are twenty species occurring on the mined lands that are not found in the forested lands and thirty forest species not found on the mined lands. Of the twenty unique mine species, many of these are typical early successional species *(Acer rubrum, Liriodendron tulipifera, Rubus* sp.*)* and many others (*Pinus* sp. and *Robinia pseudoacacia*) are offspring of the trees planted as part of reclamation efforts. Overall, there are ten more species found in the forest than on the reclaimed mined lands. This is not unusual given the very different stages of succession that these lands are in.

The data from Table 4 can also be summarized across sites by richness, defined as the number of species found regardless of abundance. Figure 4 shows that the forested category always contains more species than the sites in the reclaimed mine category, when listed from most to least rich site (i.e., the woody species are not growing in as much variety on the mined sites as in the forests.). In other words, the forests have higher plant species richness and more plant biodiversity than the mine sites (Figure 4).

Species-presence data can also be arrayed by individual species, in addition to the site values shown in Table 4 and Figure 4. Figures 5a and 5b illustrate the number and percent of transects studied where each species in the data set was found. Forested sites have a higher percent of transects represented for the majority of species. These data indicate that woody species occur across the entire forest transect, they are not just sequestered in a few unusually rich transects that happened to be included in the surveys.

There is special interest in the major tree species of the forest, as these are of possible commercial interest. Figures 6a and 6b display six of the most common hardwood tree species found by absolute number and percent of all woody stems found (total of 4,140 stems in the data sets, including all size classes). These trees are always more abundant as a proportion of stems on the forested sites. Five of the six are more common by absolute number on the forested sites; only *Acer rubrum* has more individuals on the mined sites, as many seedlings of this species were present. Further observations should be made on the reclaimed mine lands to see how well these economically viable species establish and grow.

Woody species found can also be displayed according to mine type (Table 5), to more clearly see if there are special determinants associated with species presence. Again, these numbers are based simply on being present at all, not abundance. Remnant forests have the most species, and mountaintop removal sites (MTR) have the fewest, when grouped in this way. However, only four MTR sites were examined as opposed to twenty remnant forest sites. If one examines the average number of species by site (see site table in appendix to see number of species per site), MTR's have 6.25 and remnant forests have 17.7 species on average. Table 5 also illustrates that some species (for example *Acer rubrum* and *Liriodendron tulipifera*) are more generalist (i.e. are found on all the site types). Others were found only on mined areas (*Lespedeza bicolor*) or only in forests (*Acer pensylvanicum, Lindera benzoin*). Once again, these species differences can be greatly attributed to varying successional stages.

The distribution of species can also be considered in terms of how abundant, or how frequently, the species appeared on the site (Table 6). Most species found in great number in the forests are not found in similar abundance on the mined sites. At the same time, common woody species on the mined sites, typical of earlier successional stages, are not found as abundantly in the forests. This is simply a matter of succession. The reclaimed mine lands are in a much earlier stage of succession or development than the forests, and one would expect to find different species compositions as a result of the various stages.

The forest community is comprised of a greater number of species. It is also a more diverse community than the mine land communities. More uncommon species occur in the forest and there is less dominance by a few common species. That is, the mine sites have a few dominant species making up most of their communities and few rare species present. Figures 7a and 7b illustrate the number of woody plants found during the point quarter sampling. The mine plot in Figure 7b is based on percentages, which allows a simpler comparison, as sampling effort was unequal between mine and forestlands. The mine species distribution starts quite low on the y-axis because there were many points, about 1600, where woody stems were not present at all (this very high point is not plotted on this graphic). Absence (not falling within sampling range) of a woody plant was rarely experienced on any of the forest sample points. Having more species that occur more evenly or frequently (i.e. not having a population dominated by only a few species) creates a more diverse environment. For many of the species found, the percent occurrence is high in forests. Having all the species occur only once or twice, such as on the mine lands, and being dominated by only a few species, creates a less diverse community.

There is growing concern over alien and invasive plants across all landscape types throughout the United States. This survey encountered very few invasive or alien plant species on mined-lands or in the forests (Tables 3, 7a and 7b note non-native species). Most of the non-native individuals observed were those that were planted as part of a reclamation effort (i.e. Autumn olive is both exotic and very invasive and every mine visited was using it for reclamation). There were several other exotic species that were observed, including Tree-of-heaven, Japanese honeysuckle, Princess-tree, and Multiflora rose that arrived on site naturally. Japanese Knotweed was also observed along the stream banks in developed areas.

Distribution of trees and shrubs across the study transects:

To spatially study the process of invasion, data were displayed across the x axis in figures 8-12, where “0” represents the edge, the sharp boundary between forest and reclaimed mine area. In these graphics, all alien species were removed from the data sets, as the interest in this study is the reappearance of the native West Virginia plant community. These data (in Figures 8-12) are from the twelve continuous transects described earlier (page 1). There are three Mountain-top Removal (MTR), three Valley

Fill (VF), three Backfill (BF), and three Contour Mine (CM) sites, all with paired forest remnants. The following figures graph the mean stem densities per 25m^2.

Figures 8a, 8b, and 8c illustrate the stem densities calculated for the small, medium, and large size-classes, for woody individuals on nine continuous mine to forest transects (contour mines not included in total density graphs). A "continuous transect" (Figure 3a) is a location where only one line was run, going from mine land directly into the remnant forest, or vice versa. Figure 8a shows that the small individuals (2.54cm and smaller diameter at base) are not regenerating on the mined lands as abundantly as they do in the forest. Figure 8b shows that establishment of the medium size class individuals (2.54-7.62cm diameter at base) is not as high on the mined lands as it is in the forests. (Figure 8c) Large individuals (7.62cm diameter at base) are barely present on the mining areas. There is little to no growth into this size class. This is not an unreasonable size class to reach given the age of these mines (range of 8 to 26 years old since revegetation).

The six most common forest tree species have the following age and size projections under optimum soil conditions: *Acer rubrum* can reproduce at an age as early as 4 years, with a size of 5-20cm diameter at breast height (DBH). *Quercus rubra* is 25 years at first reproduction with 60-90cm DBH. *Liriodendron tulipifera* is 15-20 years at first reproduction, with DBH of 17-25cm. *Acer saccharum* will reproduce as early as 22 years, with DBH equal to 20cm. *Fagus grandifolia* reaches substantial seed production at age 40 or with a DBH of 6cm. *Magnolia acuminata* starts reproducing at age 30, optimum at age 50, with DBH unreported (Burns and Honkala, 1990, for these data). These data should be carefully interpreted, as they are in optimum conditions, conditions that are not experienced on reclaimed mine lands. However, there are no age estimates published for such lands, with similar aspect, elevation, topography, etc. that we are aware of to compare our data to. The age and size estimates given above are at breast height, roughly 1.22m (4') high, for the average adult. The size classes used in this report were determined at the *base* of the plants, as most of the individuals were no taller than 61cm. The reclamation age of many of the mine sites is nearing or has reached the reproductive age for several of these trees, but this study's data indicates that trees in mine spoils have not approached the correlated sizes.

The woody data from reclaimed mine transects can also be divided into the four mining categories: Mountain-top Removal (MTR), Valley Fill (VF), Backfills (BF), and Contour Mine (CM). Figures 9a, 9b, and 9c illustrate the stem densities calculated for woody individuals in all three size-classes, on three MTR sites and the paired remnant forest transects. Figure 9a shows that the small individuals (2.54cm and smaller diameter at base) are not regenerating on the mine lands as they do in the forest, which is expected given the vast differences in soils. Of the three MTR's surveyed, one was eight years old since revegetation and the other two were both 17 years since revegetation. It is expected to see small size-class individuals well before 17 years is reached. The medium individuals (2.54-7.62cm diameter at base) (Figure 9b) are not present on these mined lands, and there are only a few large individuals (7.62cm diameter at base) present on the surveyed, reclaimed mine lands (Figure 9c).

Figures 10a, 10b, and 10c illustrate the stem densities calculated for woody individuals in all three size-classes on three Valley Fill sites, that accompany MTR sites, and the paired remnant forest transects. The remnant forests of two of these transects were located above the fill (Colony Bay: Cazy fill; Hobet Mine: Bragg Fork fill) and the other was located at the bottom of the fill (Leckie Smokeless: Briery Knob). Due to the triangular geometry of Valley Fills (Figure 3a), which (a) allows closer proximity to forest edge, and (b) provides a moisture gradient created by the drainage ravines at the toe of the slope, there was an increase in stem densities with decreasing elevation in the Valley Fill sites. This has apparently increased the presence of the small size-class plants in this mining area. However, the data for the medium and large size classes shows a decrease in this trend over time. Valley fills remain stressful sites for these seedlings, and slow growth or lack of survival could underlie these low data points. As these sites are ages 16, 21, and 25 years, a higher representation in all three sizes would be expected during successional change, even without optimal soil conditions.

Figures 11a, 11b, and 11c illustrate the mean stem densities calculated for woody individuals in all three size-classes on three Backfill sites and the paired remnant forest transects. One Backfill is 14 and the other two are 16 years old since revegetation. Figure 11a shows that the small size-class individuals are regenerating along the forest edge as would be expected, but taper off rapidly beyond 60 meters and are not found further from the edge. An edge effect can also be observed in the medium size-class (Figure 11b) in the first 20 meters that quickly fades until there are no medium individuals found beyond that point in great number. Few large size-class individuals were found on the mined sites (Figure 11c).

Figures 12a, 12b, and 12c illustrate the stem densities calculated for woody individuals in all three size-classes, on three Contour Mine sites and their paired remnant forest transects. All three of these sites are 12 years since revegetation. The contour mines that our investigators visited were much shorter in length than the other mine lands and were typically less compacted upon completion than flat areas, because of less grading activity (Vories and Throgmorton, 1999). Bonferroni T tests (Proc GLM in SAS/STAT version 6.12; SAS 1990) were run on the mean densities of the four mine types, by size class. The Contour Mines' plant densities in the small and medium size classes were significantly greater than all three other mine types ($p_{small} = 0.0011$ and $p_{medium} = 0.0004$) (Figure 13). Because all four mine types included in this study had so few large individuals, there was no significant difference among any of the mine treatments.

Regeneration of the small size-class individuals on the CMs illustrates the edge effect of a forest (Figure 12a). The CM's trend of regeneration falls abruptly after 10 meters, and suggests that few woody stems would be present beyond 50 meters (the local limit of this site). Figure 12b shows a pattern similar to Figure 12a, the smaller individuals are surviving into the next size class. No large individuals occurred within our sampling efforts on these CMs (Figure 12c). However, it has only been 12 years since revegetation at these sites and not many tree species are expected in this size class from seed this quickly (see maturation information in previous text).

Finally, one transect studied represents a unique site where it is possible to compare three types of land engineering, all at the same age, to determine what woody plants have naturally recruited into the site. This site was at Peerless Eagle Mine, and its age is estimated between 12 and 17 years. The top third is mountaintop removal, the middle third is a clear-cut forest remnant (apparently cut in preparation for the fill, but never filled to that height, and has since revegetated), and the bottom third is valley fill (Figure 14a). Consequently, the soil in the clear-cut area was only minimally disturbed;

soil was removed or covered in the other areas. Figure 14b illustrates the lack of plant recruitment into the two engineered areas. During the same time, the central clear-cut area has fully revegetated, probably due to stump sprouts and germination from the undisturbed seed bank (Figure 14a). Soil quality is dramatically drawn into attention at this site. In the same amount of time, with the same external forces impacting the area, there is a remarkable lack of vegetation on the engineered sites.

Additional perspectives on trees and shrubs:

Once again, comparing these data between reclaimed lands and forests is difficult, in that we do not have a controlled environment or experiment. However, we must analyze the data to the best of our abilities and within the limits of statistical powers.

The Shannon-Weiner Index (H) is a measurement of community diversity, a function of both species number and relative abundance commonly used in vegetation analysis (Barbour, et al., 1999). For small, medium and large plant size classes, the diversity index is significantly higher (paired t test, df = 8, $p_{small} = 0.0191$, $p_{medium} = 0.0082$, $p_{large} = 0.0033$) on the forested parts of the transects (Figure 15), indicating greater species diversity than on the reclaimed mine lands.

Finally, figures 16a, 16b, and 16c compare mine age (since revegetation) and average total plant density on each transect site. Data from all remnant forest transects are shown as a mean of values, with standard deviation. These are displayed across the x-axis to allow a visual comparison with all of the values from the mine lands. However, this *does not represent* in any way the actual age of the forested sites; this acts as an approximate asymptote to which developing forests in this region might attain. The data for the forest were added to give a visual cue of where the average forest density is for each size class. Figures 16a, 16b, and 16c illustrate that mine age since revegetation does not positively correlate with increasing stem density. If the densities were increasing over time, one would see a positive regression line for the mines. However, for all three size classes there is no linear relationship, indicating no increase in number of individuals over time.

The last three data points along the x-axis (reclamation ages 23, 25, 26) of figures 16a-c are important to note. The two older mines were revegetated prior to the 1977 SMCRA laws, while the third was reclaimed just two years later, in 1979. The two older sites have revegetated much more quickly than the third site and all other sites visited. The medium and large size-class individuals were just within the remnant forest density mean (or very near the lower end of the range) at these two sites. What happened in two years to create such a change in reinvasion potential? Possible answers are scale of mining and reclamation practice (see Conclusions and Executive Summary).

General Conclusions for Trees and Shrubs:

There is a low number of species and an extremely low number of stems of woody plants on all mine types in this study compared to forests. The few native plants that do invade the mining areas are very close to the edge of the forest and are heavily concentrated in the smallest size class (less than 2.54cm diameter at base). The absence of significant numbers of stems larger than 2.54cm suggests that these are stressful sites, where very slow growth or high death rates for small plants are typical conditions. These are very low invasion rates compared to many sites adjacent to mature forests that do not have mining as a land use. As has been noted in many recent studies (e.g. Vories and Throgmorton, 1999), the combination of poor substrate quality and interference by inappropriate grass cover restricts the ability of native communities to return to these extensive land areas. Stands that have regenerated on pre-SMCRA sites often have diverse, productive forests (Rodrique and Burger, 2000), but newer protocols challenge this level of stand development, as is illustrated by these data.

A 1999 Greenlands article by Skousen et al. evaluated tree growth on surface mine lands in southern West Virginia. This study examined only three sites, two of which were pre-SMRCA law, and the third was reclaimed in 1980. Our team included all three of these sites in this study of 54 sites. Skousen's results clearly support our findings in that post-law sites are not regenerating as quickly as they could due to "[herb species suppressing woody seedling establishment], soil compaction and shallow soil depth." Similarly, in the pre-law sites that were not seeded with an herbaceous cover plant succession is rapid (Skousen 1999).

An in-press article by Holl (2002) shows the potential for reinvasion and recovery on reclaimed surface mined lands. It is extremely important to note that, like the Skousen article, her study was comprised of pre-law sites dating back to 1962 reclamations. She does not report how many of the 15 sites were post-law (post 1977), but her three age classes for the mines are 1962-1967, 1972-1977, and 1980-1987. Also, the mines in that report are small ¼ hectare parcels, not comparable to the large mountaintop removal areas subject to this study. The Holl study sites, only 62.5 x 40m in size, examined areas very close to seed sources, within "5-50 m from unmined forests." It becomes obvious that invasion is possible for many species if the landscape setting is different from current large-scale practice. We have yet to see evidence that the original community has or will return to these seriously degraded landscapes.

Recently, a new series of West Virginia State regulations was passed to detail better procedures for re-establishing forest lands on AOC mine sites. These regulations include detailed requirements in soil, cover, and landscape requirements to begin getting productive habitats returning to the land. These new active regulations could be the starting point to address the poor stand development seen on the sites recorded in this study. However, full return of the rich biodiversity of the historical forests of the region would require more intervention than the addition of several dominant species, as is required in the new West Virginia regulations.

Attempts to encourage woody establishment are being made by some industry participants. One of the current practices is to plant rows or blocks of a tree species (Autumn olive, Black locust, Black alder, pine) in an effort to create corridors – areas that seed dispersers (birds, mammals) might find inviting for perching, foraging, and protection, which then introduces seed into the area. Our study found that blocks of olives and pines had little to no plants establishing underneath them. These trees were usually planted very close together and both species tend to grow dense and bush-like. Seed was either excluded from the area or could not establish due to poorer soil quality or not enough light and rain penetration. The alder and locust blocks had more success. These trees grow much straighter and do not shade out seed-rain, light, or other resources as much as the other two species. Other attempts have been made as well, like experimenting with different crop trees.

HERB STUDIES:

Presence of herbs on the study sites:

The herb communities on the forested sites were generally dense and species-rich, as is typical of this region (Hinkle et al., 1993). Eighty-five herbaceous species have been identified (Table 7a), and more were found on site, which required flowering structures for complete species identification. The presence and composition of the forest herb stratum is critical for forest health, as these herbs maintain soil structure and add nutrients, and offer habitat and nutrients to many animal species.

Three of the nineteen transects were on valley fills, the rest in forests. Presence-absence of the woodland herbs was recorded at these three valley fill sites, so these data are analyzed separately from the remaining data, which follow. Woodland herbs were not expected to be observed in open, sunny fields, as most of the herbs on Table 7a require the shade and moisture of the forest floor. The species that were recorded on the mine sites are on Table 7b.

Of the remaining sixteen sites, eleven were in mature intact forests and five were on lands directly adjacent to mining activities, such as the mine itself, a railroad, or a busy vehicular haul road. These are the "engineered" forests. Table 8 lists herbaceous species found on study sites, ranked from most to least present. The engineered forest sites are contrasted with the intact forest sites to determine the effects of mining activity on adjacent forest herbs. There might not be direct physical destruction of these adjacent forest remnants, but the disturbance caused by high activity levels (i.e. mining equipment, blasting, fumes and exhaust from train engines and hauling vehicles), as well as sun shafts cutting through to the forest floor from adjacent human-dominated areas, may disrupt the forest community starting with the herbaceous stratum. Seventeen fewer species are found in engineered forests than on intact forested sites.

In analyzing species distribution on the slopes, intact sites have more species at any point than engineered sites (Figure 17a). This can be seen with a two-way analysis of variance (ANOVA) (Proc GLM in SAS/STAT version 6.12; SAS 1990) to test for the effects of treatment type, distance from toe of slope, and the interaction of treatment and distance on mean number of species. Significant results were found for treatment type and distance from toe of slope on the species mean (both had a p value = 0.0001), indicating that both the distance up the hill and the type of site affected the number of species. There was no significant interaction between environment and distance.

The herb stratum in the intact sites also contained more stems in study areas than in the engineered sites along the entire slope (Figure 17b). A two-way ANOVA was performed, testing treatment and distance on mean number of herb stems (treatment p = 0.0016 and distance p = 0.125). Treatment type was found to be significant for number of plants found. There was no significant interaction found for distance from toe of slope on number of stems. There was no significant effect of treatment and distance collectively on number of herb stems counted.

The diversity of the herb stratum follows a similar pattern as described above. Figure 17c shows that the engineered sites had less diversity than the intact sites at all but one point along the slope. ANOVAs show a significant value (p = 0.003) for treatment type, and a marginally significant result (p = .0989), at a lower level, for distance on diversity. Once again, there was no significant relation between treatment and distance.

Tables 9a and 9b record the herbaceous species found at study sites, ranked from most to least abundant (number of stems counted) in engineered and intact sites and by percent abundance, respectively. (The two tables record absolute number and percent of stems on these sites.) Several of the species, which are found most abundantly on the intact forest sites, were not present, or were present in very low numbers, on the disturbed engineered sites. This indicates that human activity is affecting the forest ecosystem and changing the community composition. Four of the top ten intact forest herbs are in the top ten of the engineered sites, however, three of the top ten were not present at all on the engineered sites. This might indicate that although some of the heartier species are persisting, some of the more sensitive species are disappearing.

Table 10 records herbaceous species found, ranked by abundance (number of stems counted) in engineered and intact sites. In this table, values have been standardized by multiplying engineered numbers by 11/5 to even out differences in the number of sites sampled. By equalizing the numbers, one can see the abundance of the species from a level starting point. (The total number of stems for the engineered and intact forests is 3978 and 8817 respectively.) The totals indicate, even when the differing number of sites is compensated for, that the density of herbaceous stems at the engineered sites was less than half that of the intact forest sites.

General Conclusions for Herbs:

When mine disturbance is adjacent to a forest (engineered forest), we found the herb community, important for nutrient status and wildlife values, to be much less dense and species-rich. Part of the reason for the difference in spring herb abundance and diversity can be attributed to mining activity. Mining activity (i.e. filling and contour mining) often results in covering up the toe of the slope, eliminating the most diverse and rich community habitats. In our study, the engineered sites we visited *may have been* the higher slope regions depicted in Figure 18. Therefore, the habitat may have been drier and less diverse than the intact forest sites due to the fact that it was the naturally drier, higher slope community. Also, because the engineered sites suffer more intense and frequent disturbance, the quantity of light penetrating the canopy may be increased. This increase in light energy reaching the ground can dry out the soil and make conditions less favorable for the spring herb population. These herbs rarely invade mining lands on the areas studied, so data sets used for woody plants did not include forest herbs because they were seldom, if ever, observed. (Dispersal limits and the need for shady, moist microhabitat are obvious limits to regeneration.) A return to full forest biodiversity of plants is apparently even more challenged on mining areas when herb species are added to a concern.

CLOSING STATEMENT:

OSM reviewers pointed out that the unstated goal in mine reclamation in the Appalachians is to render the land green and stable. Traditionally, attempts are not made to reclaim the ecology or even the land use capability required by law. This report addresses what was accomplished, not what could be. What we see is only what is politically feasible, not technologically possible.

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